Forest Ecosystem Health

The forest community health information listed below is not all-encompassing given the broad array of both native and invasive diseases and pests affecting the forest communities of the Nantahala and Pisgah National Forests (NFs). Table 1 (below) lists many of the relevant native and non-native threats to the forest ecosystems in NC. Threats that have had a large impact or are emergent threats in forest ecosystems are described in more detail below. More information about these and other threats may be found at:
http://www.fs.fed.us/foresthealth/management/index.shtml

Table 1. Nantahala and Pisgah Forest Threats Summary

Threat ***(Bold = more information)***	**Native or Invasive**	**Species Affected**	**Impact Scale on Target Species[¥]**
Annosus Root Rot	Native	White Pine[β]	Localized
Anthracnose	Non-native	F. Dogwood, A. sycamore, B. Walnut	Widespread
Armillaria Root Rot	Native	Many	Scattered
Asian Longhorned Beetle	Non-Native	Maples	Localized
Balsam Wooly Adelgid	Non-Native	Frasier Fir	Widespread
Beech Bark Disease	Non-Native	American Beech	Widespread
Butternut Canker	Non-Native	Butternut	Widespread
Chestnut Blight	Non-Native	A. Chestnut and Scarlet Oak	Widespread
Didymo	Non-Native	Cold Water Organisms	Localized
Elm Spanworm	Native	Ash, Hickory, Walnut, Oak, Others	Scattered
Emerald Ash Borer	Non-Native	Ash Species	Widespread
Forest Tent Caterpillar	Native	Oaks, Maples, Blackgum	Scattered
Gray's Lily Disease	Native ?	Gray Lily	Scattered
Gypsy Moth	Non-Native	Oaks, Maples, Many Others	Scattered
Hemlock Woolly Adelgid	Non-Native	Eastern and Carolina Hemlocks	Widespread
Laurel Wilt	Non-Native	Laurace Family	Localized
Littleleaf Disease	Native	Shortleaf Pine[δ]	Widespread[δ]
Oak Decline	Native	N. Red, Scarlet, Black, White, Chestnut	Scattered
Oak Wilt	Non-Native	Red Oak Group	Localized
Red Oak Borer	Native	Red Oak Group > White Oak Group	Scattered
Sapstreak Disease	Native	Sugar Maple, Tulip poplar	Localized
Sirex Woodwasp	Non-Native	Many NA Pine Species	Scattered
Southern Pine Beetle	Native	Southern Pines	Widespread
Spruce Budworm	Native	Red Spruce, other conifers	Scattered
Sudden Oak Death	Non-Native	Red oak Group, Rhodo, Vaccinium spp	Localized
Thousand Cankers Disease	Non-Native	Black Walnut	Localized
White Nose Syndrome	Non-Native	Five Eastern Bat Species inc. Indiana	Localized
W. Pine Blister Rust	Non-native	E. White Pine	Localized
White-Pine Weevil	Native	E. White Pine	Widespread

[β] The disease is not prevalent in other S. pine species even though they are susceptible in other regions of the SE.
[δ] Rarely occurs on Virginia and pitch pines. Rarely occurs in the NC Mountains.
[¥] Target Species Impact Scale: Widespread>Scattered>Localized

Disease or Pest: Anthracnose

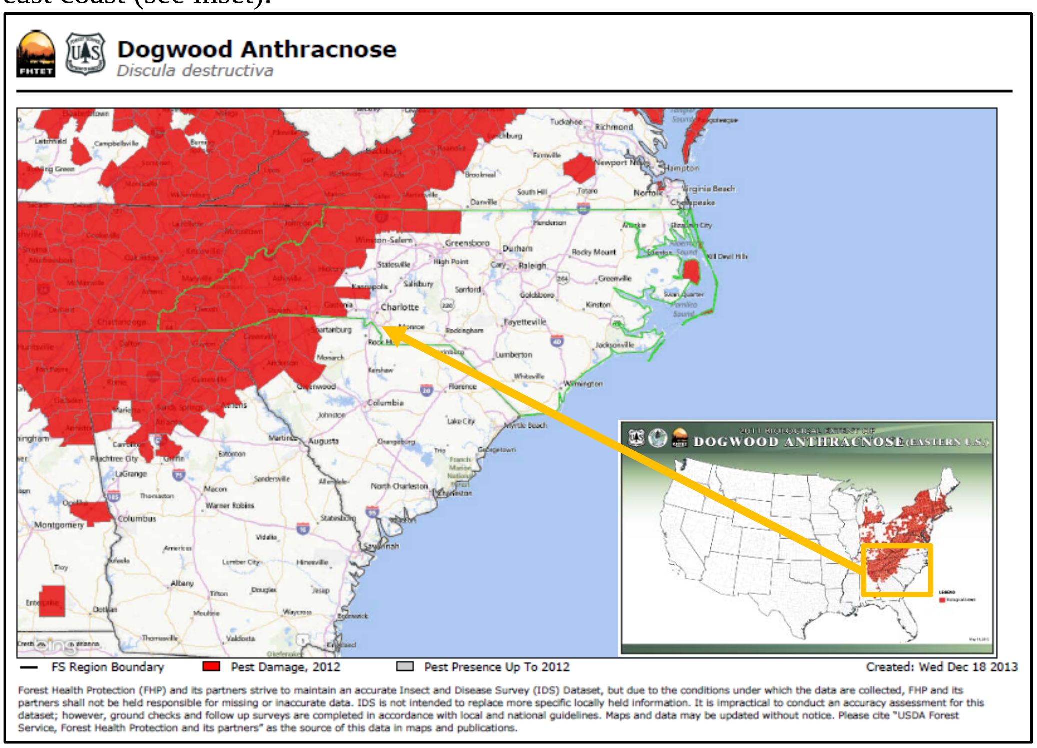
Background: Generally termed anthracnose, this genus of fungi cause leaf diseases on hardwood trees in eastern North America (Manion 1991).

Pathology: Anthracnose fungi take advantage of cool moist conditions in the spring to infect the foliage of several eastern tree species. Infection usually causes the death of tissue on infected leaves, and in extreme cases will cause cankers and mortality on twigs and branches (Skelly et al. 1990).

Forest Community Impacts: The effects of these attacks are felt the strongest by flowering dogwood, black walnut, American sycamore, and species of the white oak group (Skelly et al. 1990; Berry 1998). Anthracnose is also known to attack oaks, maples, and horse chestnut, as well as hickory and ash to a lesser extent (Skelly et al. 1990). In many instances, the health of the tree will improve with dryer and warmer weather conditions. In certain cases of stressed trees and multiple defoliations, mortality may occur.

Nantahala and Pisgah NF Distribution: Of the forest tree species that are susceptible to anthracnose in western NC, flowering dogwood may be the most at risk. Flowering dogwood is an important source of soft mast for many species of wildlife and a desirable understory tree, flowering in the spring. The dogwood anthracnose fungus was introduced into western North Carolina in the 1980s. From the period 1984 to 2006, the volume of flowering dogwood declined by 48%. In the Smokies, dogwood mortality ranged from 69-92% depending on forest community type and elevation (Holzmueller et al. 2006). In the future, it is expected that dogwoods will be largely eliminated above 3,000 feet. Trees with full exposure to the sun and/or below 3,000 feet are expected to sustain lower levels of damage.

Figure 1. Distribution of anthracnose throughout the southeastern United States and along the east coast (see inset).



Disease or Pest: Asian Longhorn Beetle

Background: Endemic to China, the Asian longhorn beetle (*Anoplophora glabripennis*) has been found in portions of the Northeastern US since the late-1990s (Sawyer and Panagakos 2009). To date, populations have been identified in urban areas within NY, IL, NJ, MA and OH (Haack et al. 2010; Ohio 2012).

Pathology: Asian longhorn beetle larva feed on the phloem and sapwood of host tree species. The adults feed on the bark and cambium of twigs and branches (Poland et al. 2001; Ludwig et al. 2002). North American longhorn beetles are more commonly known to attack dead and dying trees (Roden et al. 2009). Unaided spread rates of 1-1.4 miles have occurred in as little as five to seven years (Sawyer and Panagakos 2009).

Forest Community Impacts: Primarily considered a threat to the *Acer* genus (maples), tests indicate that Asian longhorn beetle will attack birches, elms, poplars, willows, oaks, ashes cherries, and locust (Poland et al. 2001; Ludwig et al. 2002; Roden et al. 2009).

Nantahala and Pisgah NF Distribution: There are no known populations of Asian longhorn beetle within the Nantahala and Pisgah NFs. The nearest known infestation is in southwest Ohio along the border of Kentucky. However, given the wide range of host species preferred by the Asian longhorn beetle, the impact of widespread infestations could be great (personal communication P. Merten).

Disease or Pest: Balsam Woolly Adelgid

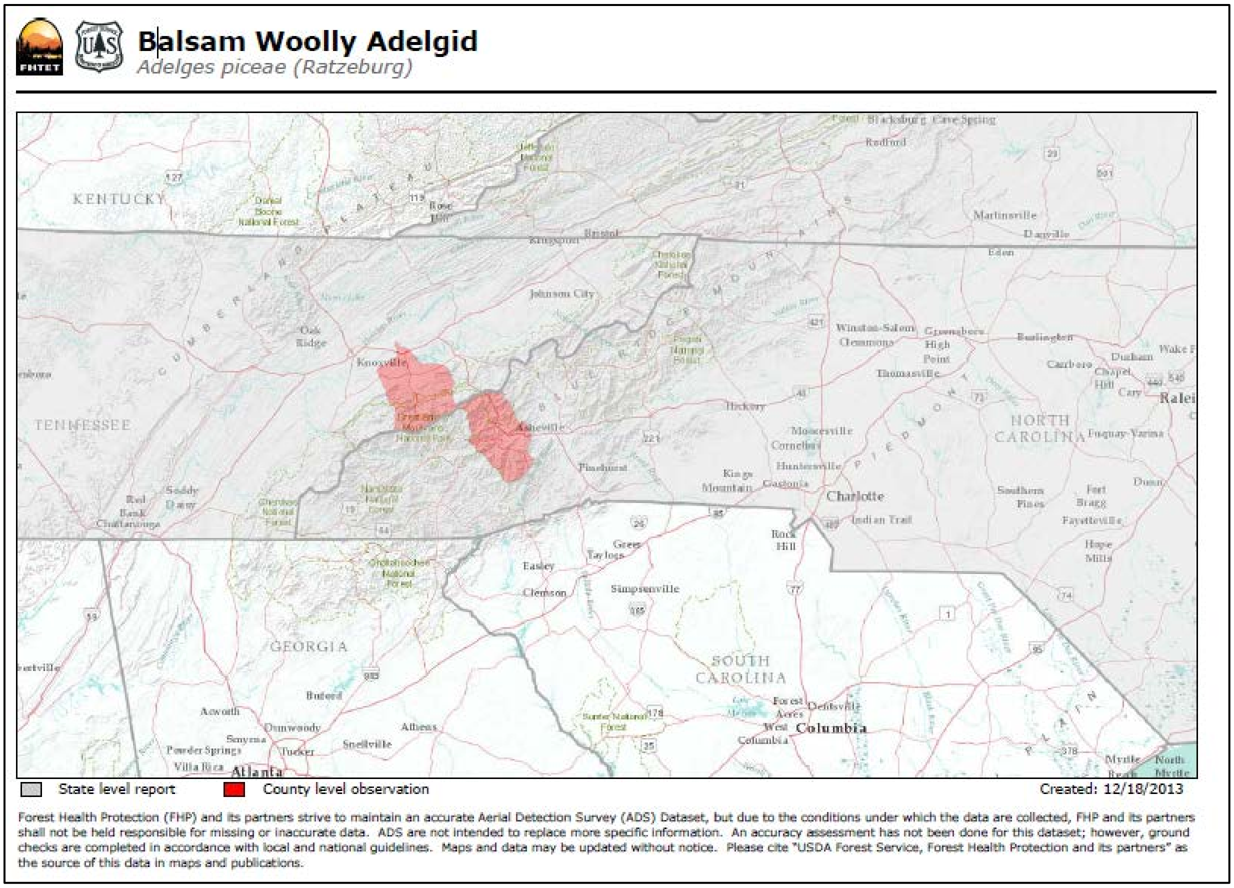
Background: The balsam woolly adelgid (*Adelges piceaeis*) is a nonnative invasive insect that is believed to be native to parts of central Europe (Hain et al. 1991). Though it was thought to have entered North America around 1900, the balsam woolly adelgid was not identified on the continent until 1955, when it was found impacting the fir in Mt. Mitchell State Park, NC (Hain et al. 1991). Once it was discovered, the balsam woolly adelgid moved rapidly south through remaining stands of spruce-fir forest; its presence was established in all communities by the late 1960s (Smith and Nicholas 1999). During the height of the infestation in western North Carolina in 1965, mature fir mortality was estimated to be close to 2.5 million trees (Amman 1966).

Pathology: The adelgid feeds on the sap of Frasier firs by attacking the bark. Serious infestations cause crown dieback and eventual mortality. Infestation by balsam woolly adelgid results in a change in the tree’s wood structure and contributes to decreased water transport throughout (Hain et al. 1991).

Forest Community Impacts: Stands dominated with greater than 50% Fraser fir cover decreased by close to 80% between 1954 and 1988 (McManamay et al. 2010). Seedlings and saplings are not subject to attack at levels that cause serious harm, but mature trees can die between one to eight years after infestation (Amman 1966). Consequently, developing stand structures appear to have the same species composition as the disturbed forests, but the trees are of smaller size classes (Bowers and Bruck 2010; Lusk et al. 2010). Smaller spruce and fir trees are capable of reaching maturity where fir is commonly killed again by balsam woolly adelgid after one to two years of successful seed production (Lusk et al. 2010; Nowacki et al. 2010; Rhea, personal communication).

Nantahala and Pisgah NF Distribution: Balsam woolly adelgid is present throughout the spruce-fir ecozone in western North Carolina. The insect appears to be operating in a patchy distribution as smaller groups of fir grow to sizes that permit infestation (Bowers and Bruck 2010; Lusk et al. 2010; Rhea, personal communication; White and Walker unpublished data), but this is not occurring uniformly across the ecozone. There is research indicating that Fraser fir is not following a regeneration-mortality trajectory in parts of the ecozone (McManamay et al. 2010). Currently balsam woolly adelgid is most active within high elevations of Haywood County, NC.

Figure 2. Distribution of the balsam woolly adelgid in North Carolina and Tennessee.



Disease or Pest: Beech Bark Disease

Background: The nonnative beech scale insect (*Cryptococcus fagisuga*) and canker fungus (*Neonectria faginata*) were introduced in North American around 1890 from Halifax, Nova Scotia. The disease has slowly moved south and west through the northeastern US with conservative spread rates of nine miles/year (Morin et al. 2007). Infestations by the scale insect first appeared in the high elevations of northern hardwood forests and the beech gaps of western North Carolina in the early 1990s. Departures from the continuously advancing front are hypothesized to be related to the accidental transport of infected beech material by humans (Morin et al. 2007).

Pathology: Beech bark disease begins as the beech scale feeds on the tree. The feeding is then followed with an attack by the canker fungi, which invades and destroys the tree's bark and cambium structures.

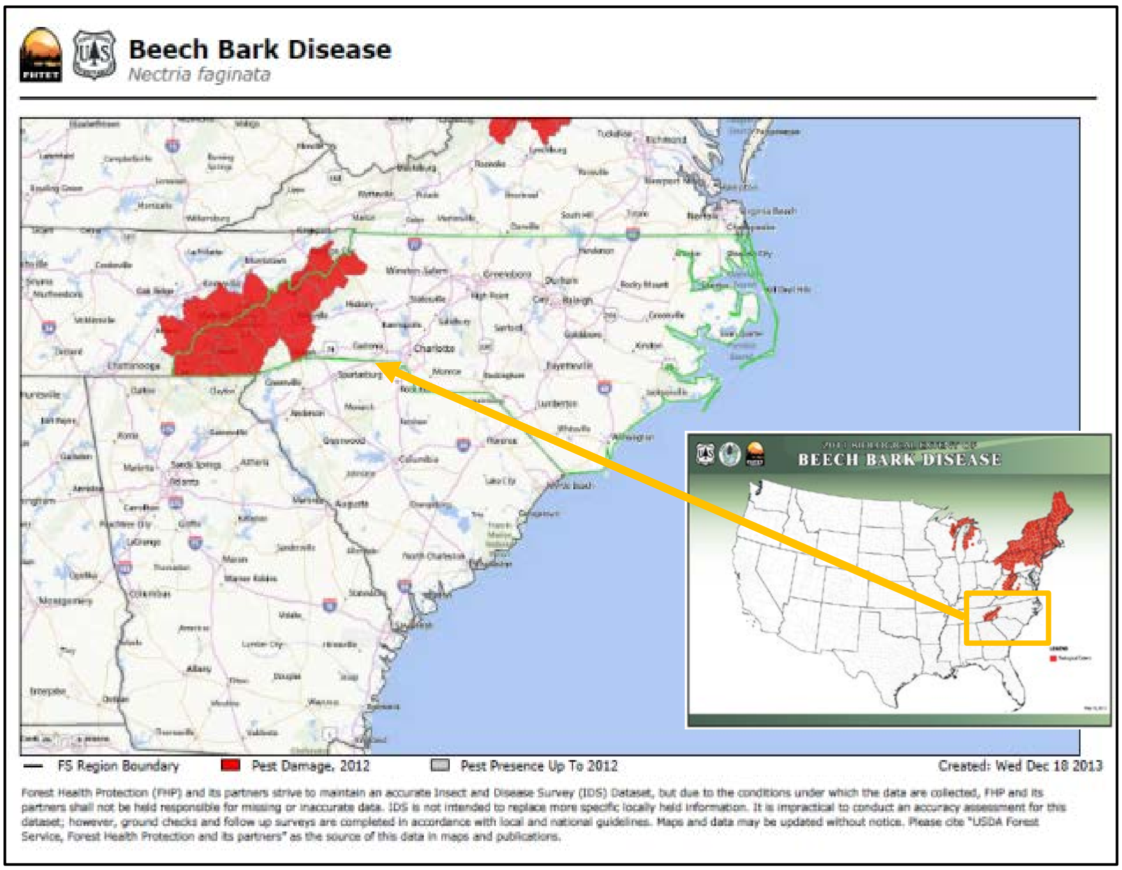
Forest Community Impacts: Beech bark disease dynamics spread in three phases:

(1) The scale insect invades a healthy beech community, advancing the front;

(2) The fungal infestation follows, with tree dieback typically beginning three to five years after the introduction of the fungus; and

(3) In the aftermath, the community struggles to restructure as the disease becomes endemic (Houston 1994).

Figure 3. Distribution of beech bark disease throughout the southeastern United States and along the east coast and midwest (see inset).



Throughout the three phases of beech bark disease, the beech tree may lose many of the larger trees in the community and suffer high rates of mortality (in some cases, 80-95%) (Houston 2004; MacKenzie 2004). Due to beech's clonal habits, and its ability to sprout (and sucker), a structural shift occurs as dense beech concentrations in the midstory dominate local forest conditions (MacKenzie 2004). These "beech thickets" reduce understory light levels resulting in reduced herbaceous diversity and limited tree species regeneration. These conditions also perpetuate the scale and fungal populations as beech seedlings are continually re-invaded and killed as they sprout (Morin et al. 2007).

Nantahala and Pisgah NF Distribution: Virtually all high-elevation beech stands and beech gaps in western North Carolina are impacted by beech bark disease. In many locations, species and structural shifts have already occurred. Across the landscape, the American beech is limited to small clonal clumps or stands of scattered individuals.

Disease or Pest: Butternut Canker

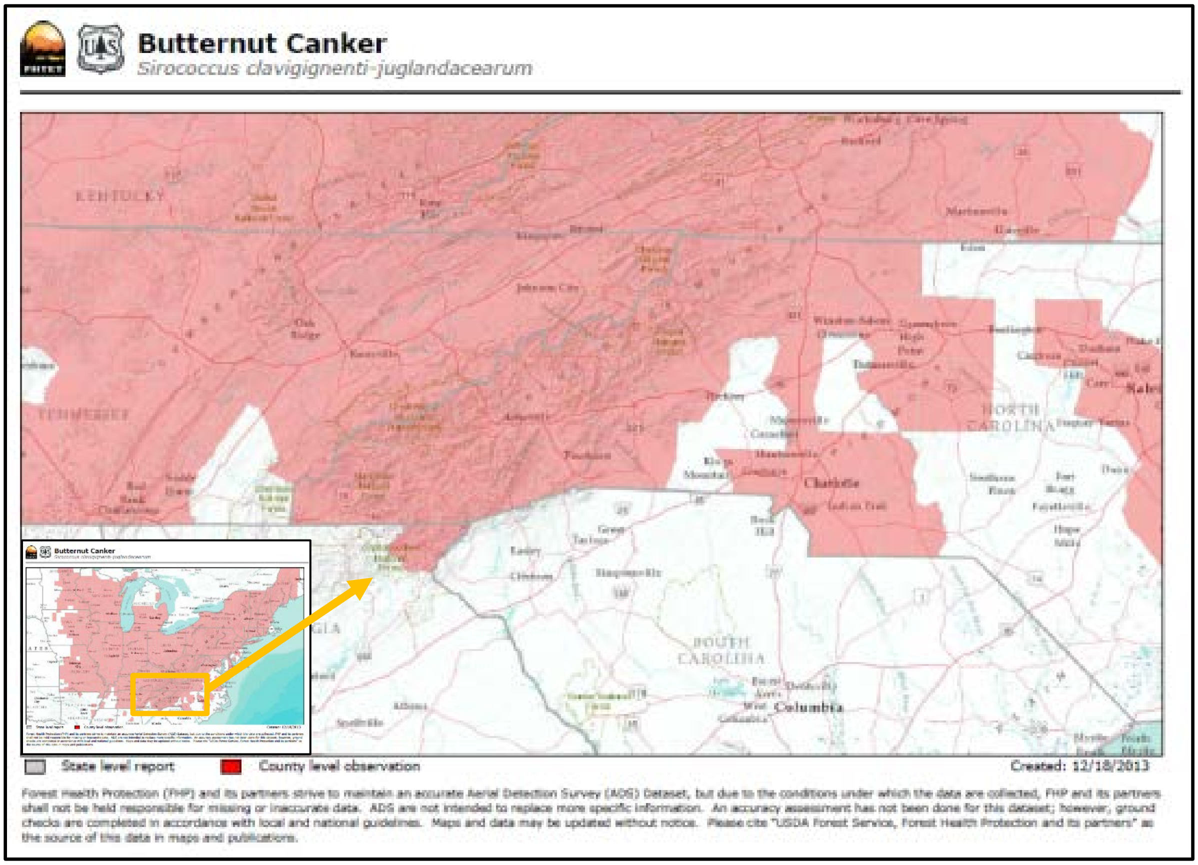
Background: Butternut canker (*Sirococcus clavigigenti-juglandacearum*) was first identified in southwestern Wisconsin in 1967. It is now threatening butternut trees throughout its range (Ostry et al. 1996). Other species from the *Juglans* family are also susceptible, but have much higher rates of survival (Schultz 2003).

Pathology: The fungus infects the tree through leaf scars and other small wounds, resulting in dieback in upper portions of the tree. Insects and wildlife also transport the disease. Rainfall transfers the infection to the main stem resulting in cankers that girdle and kill the tree (Ostry et al. 1996). Trees of all ages are susceptible (Schultz 2003).

Forest Community Impacts: Mortality has approached 80% for butternut across its range (Ostry et al. 1996), which experienced at least 77% of this dieback in the southeastern US by 1995 (Schlarbaum et al. 1997). Loss of genetic and biological diversity is of great concern with regard to the decline of butternut in eastern forests.

Nantahala and Pisgah NF Distribution: Butternut is typically found in low abundance throughout mid and lower elevation forest communities. The species was reported to be almost completely extirpated by the late 1970s in North Carolina (Anderson and LaMadeleine 1978), and in the mid-1990s the southern region of the Forest Service joined a coalition to identify butternut populations in the field, complete resistance screening, and plant progeny tests (Schlarbaum et al. 1997). Some of this work has occurred on the Nantahala and Pisgah NFs, which list butternut as a sensitive species today.

Figure 4. Distribution of butternut canker throughout the southeastern United States and along the east coast and midwest (see inset).



Disease or Pest: Chestnut Blight

Background: The fungus that causes chestnut blight (*Cryphonectria parasitica*) was introduced to North America in New York in 1904. From NY, the fungus spread quickly throughout chestnut populations in the US over a period of less than 50 years (Diller 1965).

Pathology: The fungus infects the bark of the tree through wounds forming a canker that girdles the tree at the site of infection. Cankers on the stem will girdle the entire tree. The fungus does not infect the portion of the tree that is below ground (Diller 1965).

Forest Community Impacts: The fungus that causes chestnut blight also damages chinkapin species and may also be found on maples, hickory, sumac, and scarlet oak (Diller 1965). The loss of the American chestnut has drastically changed the composition of second growth forests in western North Carolina. These forests struggled to regenerate after large-scale timber harvest cleared the area between the late 1800s and mid-1900s. The loss of the species gave rise to the oak-dominated forests of today. Chestnut sprouts from the original root systems (which are over 100 years old) are still found in the forest today, and many of these sprouts have siblings standing nearby that have been killed by blight. They stand as a testament to continued presence of the fungus.

Nantahala and Pisgah NF Distribution: Chestnut blight reached the mountains of North Carolina in the mid-1920s (Diller 1965). The forests present in the Nantahala and Pisgah at that time contained between 30 and 60% chestnut (Wang et al. 2013, McNabb personal communication). Today many of the acres that contained American chestnut during the blight still contain remnant root systems that foster small sprouts. Since 2009, the Nantahala and Pisgah NFs, in agreement with the Southern Research Station, The University of Tennessee, and the American Chestnut Foundation (TACF), have been implementing test plantings on small acres of national forest lands to test the blight resistance. More information on restoration efforts may be found at http://www.fs.fed.us/r8/chestnut/index.php.

Disease or Pest: Didymo

Background: Didymo (*Didymosphenia geminate*), commonly referred to as rock snot, is a unique and very large freshwater benthic diatom native to Europe. Though present in Canada in the late 1800s, didymo did not begin to cause problems in the US until the early 1990s. Its presence was ubiquitous in rivers throughout the western US by 2004, and it was first identified east of the Mississippi River in Tennessee in 2005 (USDA 2012).

The individual diatoms are microscopic, with a stalk that separates into two branches when the cells divide such that one diatom becomes entangled in the next as they grow. This eventually leads to the development of mats of diatoms which spread across the stream bottom. The mats are strong and resistant to degradation. They are not slimy, but instead feel fibrous like wet cotton or wool. They are pale yellow-brown to white in color (USFWS 2012).

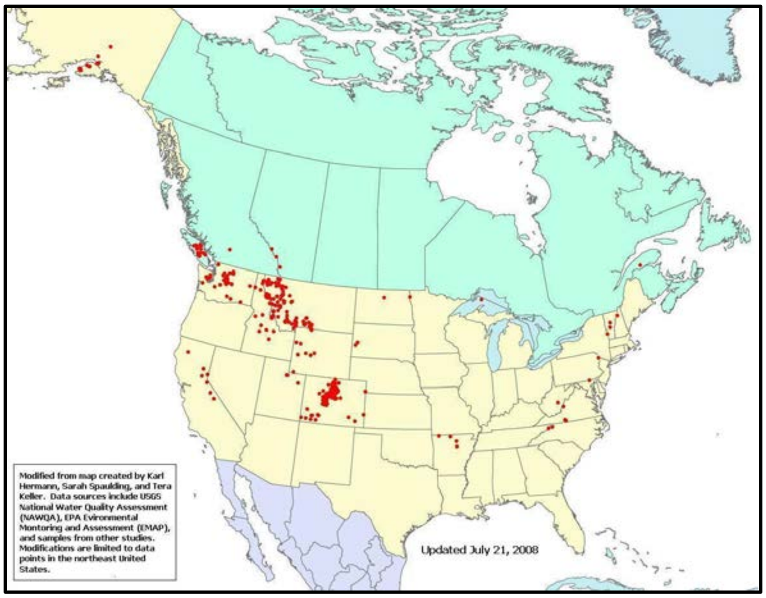
Pathology: The local pattern of distribution suggests that didymo is spread by recreational anglers. The diatom is so small that a drop of water can aid its spread. The management control for human transfers is to (1) check all gear and remove visible clumps; (2) clean all gear by soaking and scrubbing for at least one minute in either hot water that is 140^{o}F or with a 5% solution dishwashing detergent (one cup detergent per one gallon water); and (3) dry all gear thoroughly - it must be completely dried and then re-dried 48 hours before use. If recommended cleaning and drying methods are not possible, restrict use of gear to a single water body and use different gear for infested areas.

Forest Community Impacts: Mats of didymo can result in dense algal blooms that block sunlight and disrupt ecological processes, causing a decline in native plant and animal life. Aside from the aesthetic appearance of an infested river and a general safety hazard for anglers and other river users (slippery rocks), there does not seem to be a negative impact on trout or other fish populations living in infested streams in Norway, Quebec, Scotland, Finland, Iceland, or France because viable food sources remain. (USFWS 2012).

This diatom prefers cold, oligotrophic streams with stable flows, hard/stable substrates, Ca>2mg/l, and a high nitrogen to phosphorous ratio. Didymo can attach to plants, is rarely found in lakes, needs a lot of light, and thrives under increased ultraviolet conditions. Floods seem to provide a natural control for didymo (USFWS 2012).

Nantahala and Pisgah NF Distribution: Didymo is not known to occur in North Carolina. In 2008 and 2009, the National Forests in North Carolina, Great Smoky Mountains National Park, and the North Carolina Wildlife Resources Commission reviewed available stream chemistry data to evaluate the risk of introduction into North Carolina waters since anglers routinely cross to and from waters in infected states. While this risk was determined to be low to moderate, it is possible that if introduced, didymo could survive in some waters within the forestlands. Angler access areas are now posted with decontamination protocols.

Figure 5. Distribution of didymo in United States.



Disease or Pest: Emerald Ash Borer

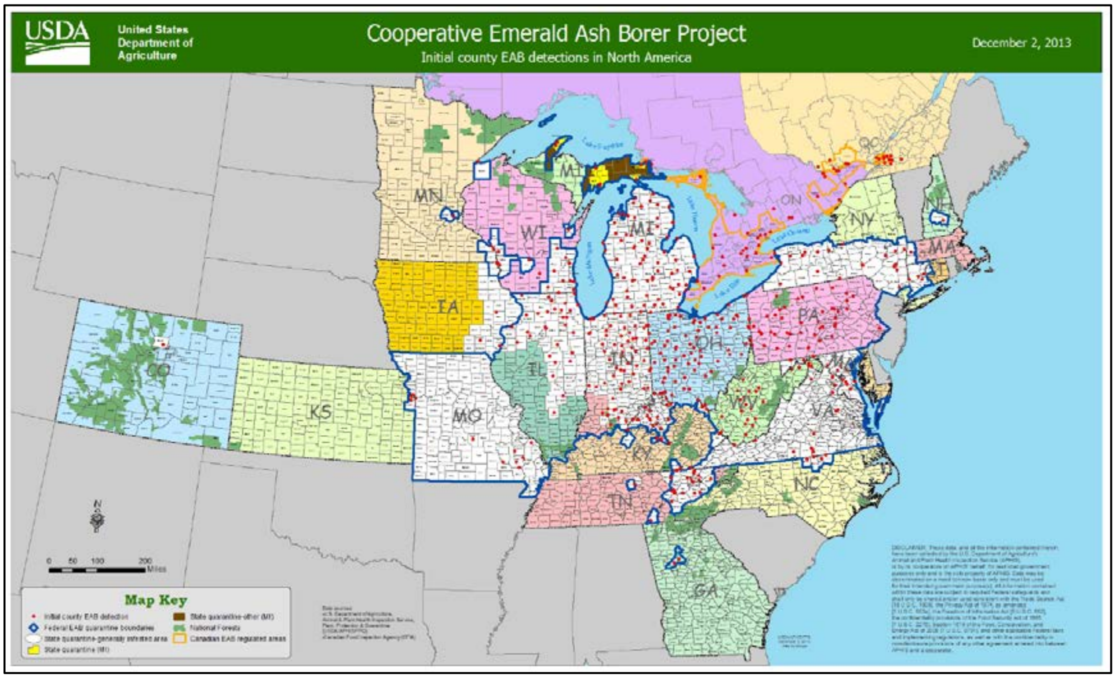
Background: Accidentally introduced in Michigan near Detroit in the early 1990s (Poland et al. 2010), this invasive insect from Asia (*Agrilus planipennis*) was found in 21 states as of December 2013. Similar to other forest pests, the emerald ash borer is easily dispersed by humans transporting ash products such as firewood or logs, thus creating random pockets of infestation that are exacerbated by the adult female's natural rate of spread (Mercader 2011).

Pathology: Emerald ash borer is a phloem-feeding beetle that specializes in the ash species. Adult females first deposit their eggs on the bark, and after hatching the insect burrows under the bark creating galleries, ultimately girdling the tree (Mercader 2011; Petrice and Haack 2011). After infestation, mortality of mature ash trees exceeds 96% within six years (Knight et al. 2010). Emerald ash borer represents a serious threat to North American ash species (Pugh et al. 2011).

Forest Community Impacts: High levels of mortality in ash species create gaps and openings in the forest canopy. Ash trees will regenerate and grow to seedling and sapling sizes (until roughly one inch in DBH) when they are attacked by baseline levels of the emerald ash borer that are now present in the forest. The density of ash in the forest does not correlate with the rate of infestation with scattered ash trees being attacked at similar rates as dense stands of ash (Knight et al. 2010; Petrice and Haack 2011). The adult females of the species appear capable of finding small populations of ash trees across the landscape as the availability of ash trees decline within existing population centers (Mercader 2011).

Nantahala and Pisgah NF Distribution: Ash species are present in the Nantahala and Pisgah NFs as a scattered component within several forest types and ecologic communities. With emerald ash borer able to locate and attack scattered pockets or individual trees, the species as a whole is in serious jeopardy. Though not located in the Nantahala and Pisgah NFs, emerald ash borer is present in counties immediately to the west in Tennessee. Emerald ash borer is also present in the north central portions of North Carolina.

Figure 6. Distribution of emerald ash borer throughout the United States.



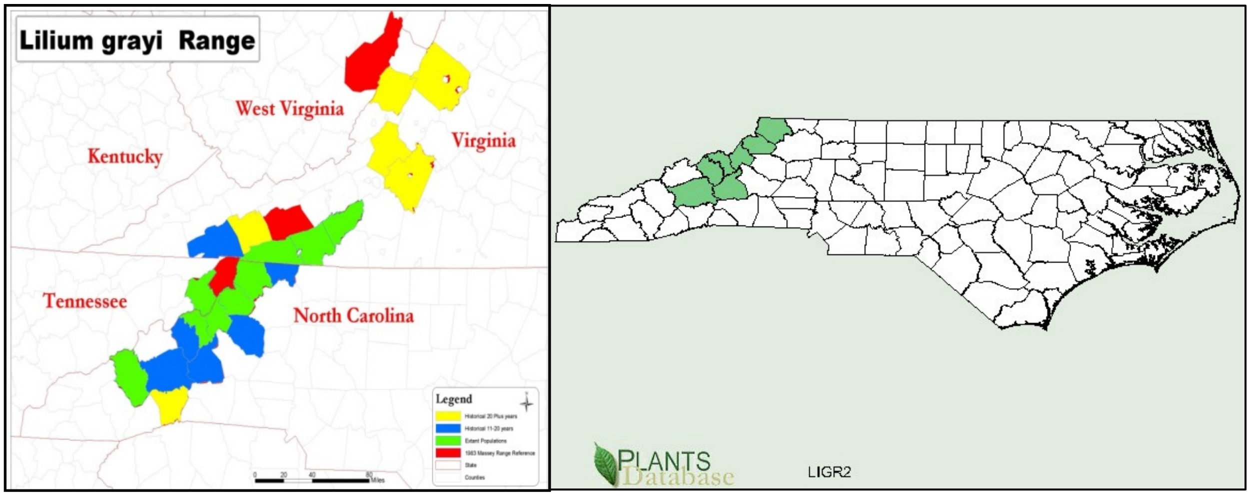
Disease or Pest: Gray's Lily Disease

Background: Gray's lily is a perennial herb that is endemic to balds, bogs, seeps, streams and forest openings at mid- to high elevations in North Carolina, Tennessee, and Virginia. It was first identified in 1879. This lily is threatened by vegetative succession, the suppression of wildfire, overgrazing, mowing, and overharvesting. Gray's lily disease (a fungus) infects and kills the plant before the plant reaches reproductive maturity.

Forest Community Impacts: Gray's lily is federally listed as a threatened species. Continued pressure by the above mentioned threats, especially the fungal pathogen, may lead to accelerated reduction in the limited abundance of this species.

Nantahala and Pisgah NF Distribution: In North Carolina, Gray's lily is found on Roan Mountain in Mitchell and Avery Counties. Long Hope Valley in Ashe County, North Carolina possesses the largest known populations of this species. The Gray's lily is currently on the Regional Forester's Sensitive Species List.

Figure 7. Distribution of Gray's lily disease throughout North Carolina and neighboring states (left) and prevalence of the fungus in North Carolina only (right).



Disease or Pest: Gypsy Moth

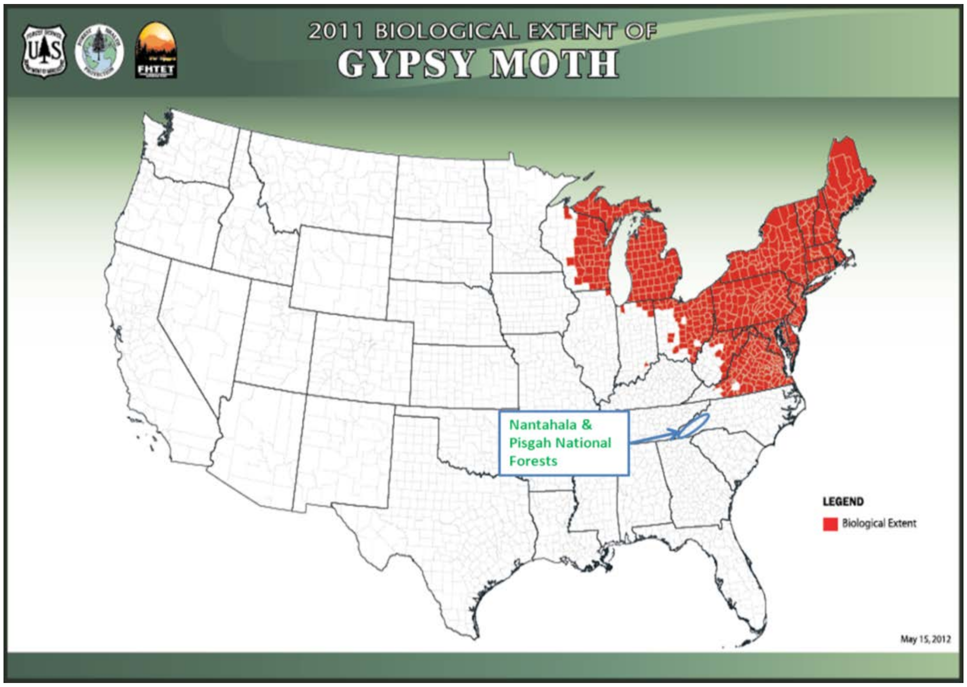
Background: Introduced in the US in 1869 (McManus et al. 1989), the gypsy moth (*Lymantria dispar ssp.)* is now permanently established in 17 states.

Pathology: During the caterpillar stage, the gypsy moth consumes the foliage of desirable tree species. Populations very quickly reach epidemic levels causing widespread defoliation. Dense gypsy moth populations may last for two to four years (McManus et al. 1989) with outbreaks generally occurring between eight to ten years (Tobin et al. 2012). Movement of the species occurs when a larval "balloon" or egg mass is transported from an infested tree to a nearby tree; most all movement is aided by humans (Tobin et al. 2012).

Forest Community Impacts: Gypsy moths feed on a wide variety of trees, shrubs, and vines, but prefer all oak species, apple, beech, birch, basswood, and willow. Multiple defoliations of forest tree species may result in the mortality of stressed trees. Otherwise, gypsy moth exposure makes trees vulnerable to other killing agents. In oak species, defoliation by gypsy moth may lead into an oak decline scenario.

Nantahala and Pisgah NF Distribution: Although the gypsy moth is not yet permanently established in the Nantahala and Pisgah NFs, there have been numerous instances of human introduction of the pest over the past 10-15 years. A few of these introductions developed into small, isolated pockets of infestation that were subsequently eradicated. Additionally, the Forest Service is implementing a program to slow the spread which will delay the establishment of gypsy moth in western North Carolina. The entire state has been monitored for gypsy moth populations since 1982. Trapping results from 2011 show that the majority of advancing gypsy moths were caught in northern NC. Of the 18 counties in the western NC NFS lands, four found evidence of gypsy moths in 2011: Burke, Caldwell, Watauga, and Clay.

Figure 8. Distribution of gypsy moth in the US.



Disease or Pest: Hemlock Woolly Adelgid

Background: First identified in Virginia in 1951, this small aphid-like insect (*Adelges tsugae*) covers over half the range of eastern hemlock species (FHP 2005).

Pathology: The hemlock woolly adelgid feeds by inserting a feeding tube into a host tree at the base of the needle. They feed on the tree's stored starches. The species is most commonly spread by wind and animals, though humans frequently aid long distance dispersal (FHP 2005). Mortality of infected hemlock trees averages greater than 90% (Mayer 2002).

Forest Community Impacts: Hemlock woolly adelgid directly effects both eastern and Carolina hemlock. Decline and mortality usually takes four to ten years but has occurred more quickly in the southern US (FHP 2005). Loss of hemlock forests near streams poses a threat to aquatic species (such as brook trout) adapted to certain types of stream communities. Streams receiving drainage from hemlock forests are known to have higher species richness than similar hardwood forest drainage sites (Snyder et al. 2005).

In 2002, Forest Inventory and Analysis data indicated that western NC contained over 95 million hemlocks one inch or greater in diameter, of which approximately 32 million, or about one third, were on National Forest System lands (appendix C, USDA-FS 2004). With mortality rates above 90%, the Nantahala and Pisgah NFs could potentially lose 28 million hemlock trees, if they have not already lost as many.

Nantahala and Pisgah NF Distribution: The hemlock woolly adelgid has been a part of western NC for more than a decade. First found in the forests in 2001, and mortality had started to develop by 2004. It now inhabits the entire native range of both eastern and Carolina hemlocks in the state (FHP 2005). The Nantahala and Pisgah NFs have been treating both eastern and Carolina hemlocks for hemlock woolly adelgid since 2005, using both chemical treatments and the release of biological predators to the combat spread of the pest. The Nantahala and Pisgah NFs have roughly 2,500 acres of hemlock currently under treatment with insecticides or biological control.

Figure 9. Distribution of hemlock woolly adelgid throughout the southeastern United States and along the east coast (see inset).

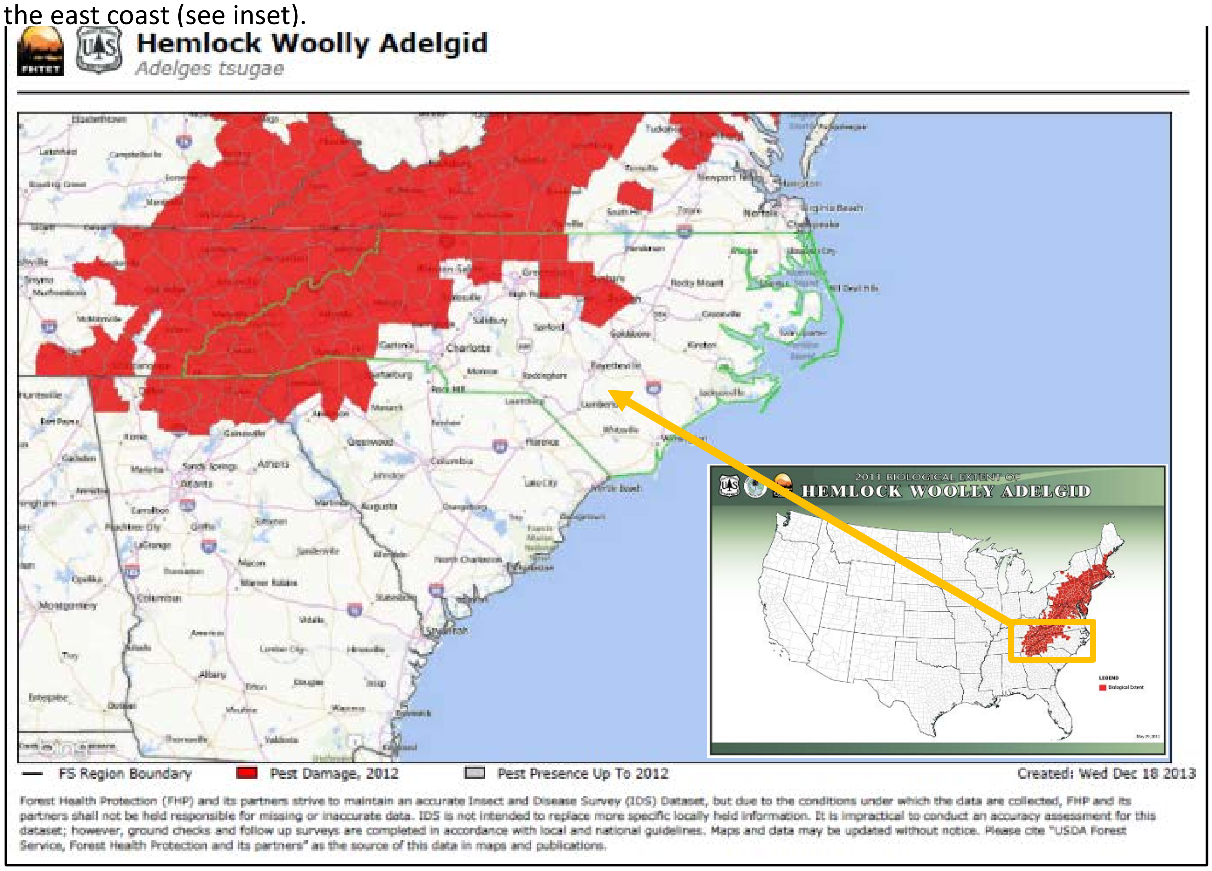
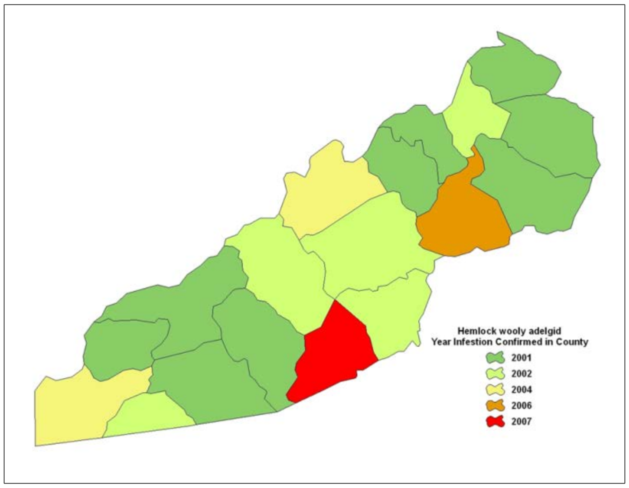


Figure 10. Inception of hemlock woolly adelgid in counties across western North Carolina.



Disease or Pest: Laurel Wilt

Background: Laurel wilt was first noticed in the US near Savannah, Georgia, in 2002.

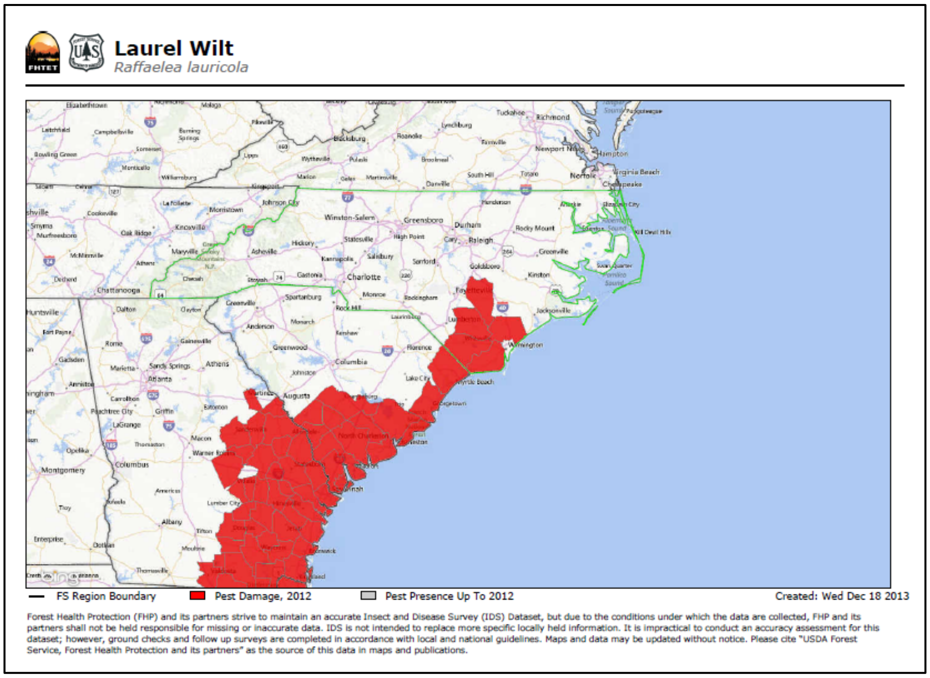
Pathology: Laurel wilt is caused by a nonnative invasive ambrosia beetle/fungus combination from Asia (*Xyleborus glabratus/Raffaelea lauricola*). The fungus is deposited into host species as the female beetle searches for suitable sites to lay eggs. The fungus then enters the vascular system of the tree causing wilt, dieback, and ultimately, death (Gramling 2010).

Forest Community Impacts: The redbay ambrosia beetle attacks all species within the *Lauraceae* family (Mayfield et al. 2008). The rate of spread of this beetle has been estimated at 34 miles/year (Koch and Smith 2008), and human-aided distribution is suspected. Mortality rates within host species are high (Fraedrich et al. 2008) and have been documented as high as 95% amongst redbay populations (NCDOF 2011).

Nantahala and Pisgah NF Distribution: Though not currently known in the Nantahala and Pisgah NFs, this disease was present within several eastern NC counties in 2011, as well as in SC, GA, and FL (NC 2011). Sassafras is the most widely distributed species in the *Lauraceae* family across the Nantahala and Pisgah NFs and therefore, most at risk in the event of laurel wilt infestation.

Sassafras is a common but minor component in many of the forest communities. Other species with documented susceptibility include northern spicebush, pondberry, bog spicebush, and pondspice. Loss of these species may have far-reaching impacts on wildlife populations such as that of the spicebush swallowtail (Gramling 2010). Until a recent infestation of sassafras in Alabama, only redbay populations were impacted by laurel wilt.

Figure 11. Distribution of laurel wilt throughout the southeastern United States.



Disease or Pest: Oak Decline

Background: Oak decline involves a host of drivers including climatic stress, inadequate physical site condition, pests, pathogens, and tree age, the combination of these drivers resulting in the slow decline and eventual death of individual oaks or groups of oak trees (Kessler and Houston 1989; Manion 1991). Oak decline has occurred throughout the range of oaks (Wargo et al. 1983).

Pathology: Oak decline occurs in three progressive levels. In the first stage, the health of the physical site is compromised, limiting growth (Manion 1991). Unhealthy sites are characterized by a lack nutrients in the soil, as well as inappropriate soil depth and texture (these are called predisposing factors). Oak trees that appear healthy on the outside are then stressed by one or more inciting factors such as late spring frosts, successive droughts, waterlogged soils, defoliating insects, and diseases such as gypsy moth or anthracnose (Kessler and Houston 1989; Manion 1991). Root reserves of the tree are then used by the tree to recover from the stress, weakening the root system and possibly leading to infection by armillaria root rot (*Armillaria mellea*) or attack by wood boring insects like the two-lined chestnut borer or the red oak borer (known as mortality-causing organisms) (Kessler and Houston 1989; Oak et al. 2004). This decline process takes several years (two to five) and eventually leads to the death of the tree.

Forest Community Impacts: Oak decline affects all oak species. There is some indication that species within the red oak group are affected more than those in the white oak group (Oak et al. 2004). Often the scale of the decline is related to the scale of the initial stressor, the population size of *armillaria*, and the population size of the two-lined chestnut borer. Oak decline can be shown through individual tree decline and clustered decline of trees across the landscape.

Nantahala and Pisgah NF Distribution: Within the Nantahala and Pisgah NFs, oak species are among the most dominant trees. Roughly 70% of Nantahala and Pisgah NFS lands currently have an oak overstory or oak understory component. From 1984 to 1997, the incidence of oak decline in North Carolina increased from roughly 10% to greater than 19%. Western NC in particular was noted, the area having high densities of oak in decline (Oak et al. 2004).

Disease or Pest: Oak Wilt

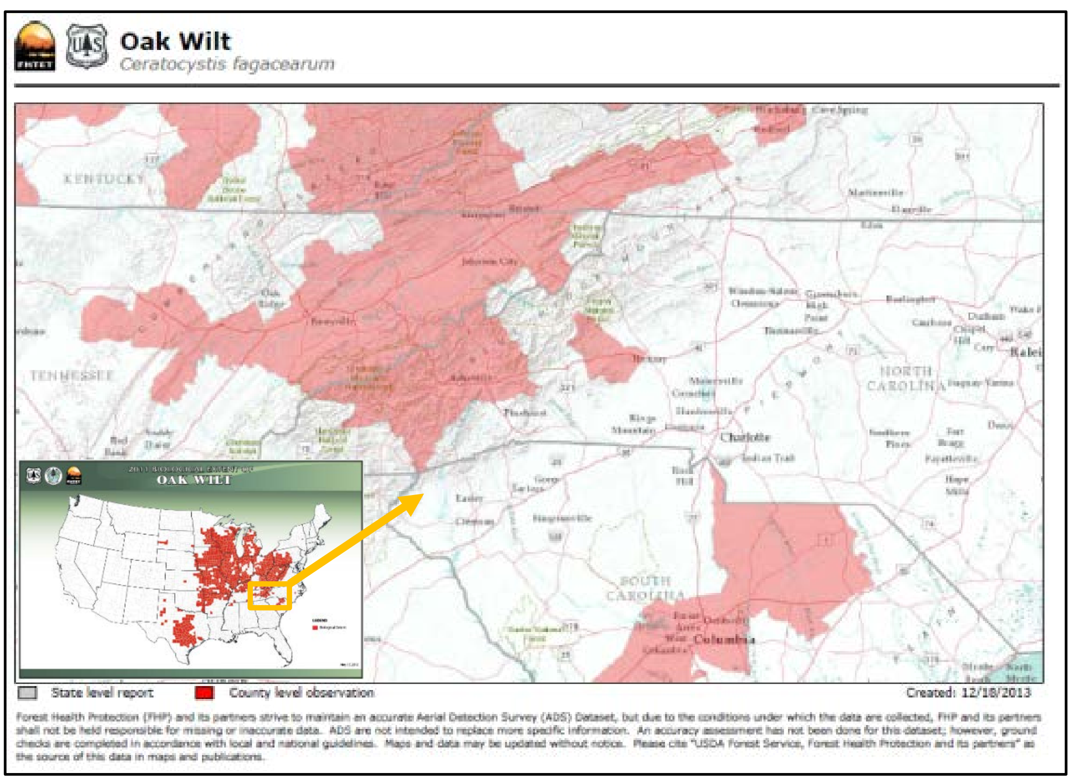
Background: First identified in 1944, oak wilt is caused by a fungus suspected to be nonnative in the eastern US (*Ceratocystis fagacearum*). It is thought to have arrived in North America in the early 1900s (Koch et al. 2010; O'Brien et al. 2010).

Pathology: Oak wilt spreads through natural root grafts that occur between trees or through sap and bark beetle colonization of physical wounds. The fungus leading to wilting and death compromises the vascular system of the infected tree. In the red oak group, this progression is rapid (several weeks to months) while white oaks may take years to succumb. Live oaks are intermediate in their rate of mortality (O'Brien et al. 2010; Juzwik et al. 2011). Human spread of infected tree materials is another source of new infections (Koch et al. 2010).

Forest Community Impacts: Oak wilt is one of the most serious diseases to affect oak species in the eastern US (Koch et al. 2010; O'Brien et al. 2010). Out of the three eastern oak groups, red oaks are the most susceptible to the disease, with both white oaks and live oaks showing some level of physiological resistance (Koch et al. 2010; O'Brien et al. 2010; Juzwik et al. 2011).

Nantahala and Pisgah NF Distribution: Oak wilt is rather slow to spread (Juzwik et al. 2011). It has been identified within counties included in the Nantahala and Pisgah NFs.

Figure 12. Distribution of oak wilt throughout western North Carolina and surrounding states and throughout the United States (see inset).



Disease or Pest: Sirex Woodwasp

Background: The wasp (*Sirex noctilio*) is native to Europe, Asia and North Africa where it exists as a secondary pest.

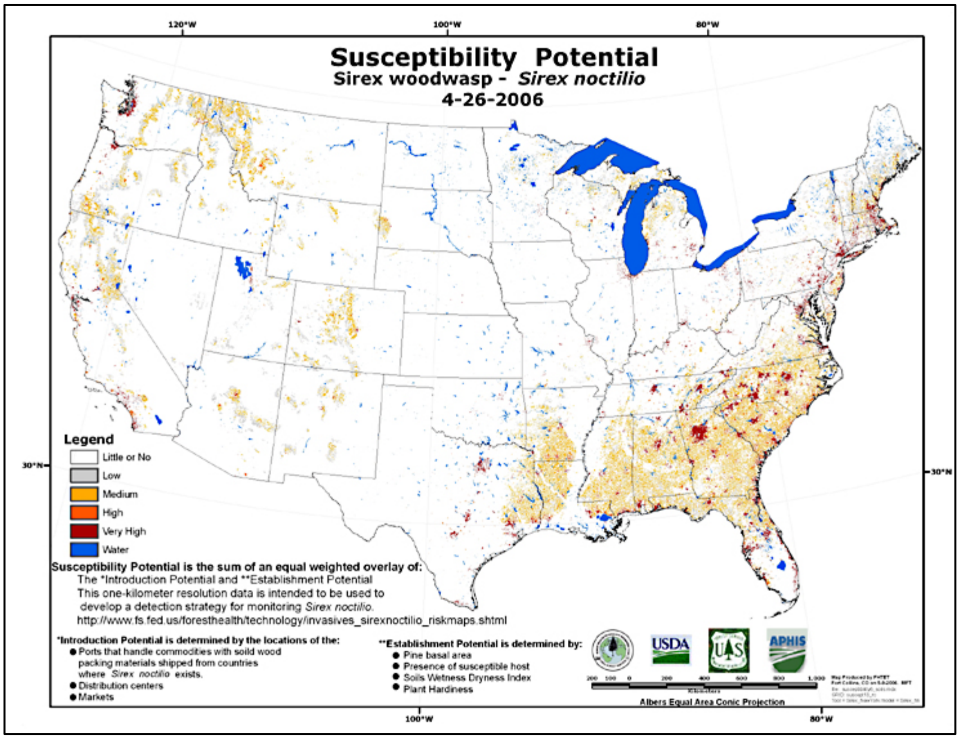
Pathology: The female wasps drill their ovipositors into the outer sapwood to inject a symbiotic fungus (*Amylostereum areolatum*), toxic mucus, and eggs. The fungus and mucus act together to kill the tree. The larval wasps feed on the fungus as they tunnel through the wood.

Forest Community Impacts: This insect has the potential to cause significant mortality in pine species. Infestations in South American pine plantations containing loblolly pine resulted in up to 80% tree mortality (Haugen and Hoebeke 2005). Many North American pine species are known to be susceptible (Pears and Wallin 2011; NYS_DEC 2012). The wasp attacks living pines regardless of tree health.

Nantahala and Pisgah Distribution: Though there are no populations currently known in North Carolina or areas south of Pennsylvania, predictive models using the current rate of spread indicate that the wasp could be present in VA and NC within the next 10 years without human-aided movement. Losses in southern pine could reach 275 million dollars (USDA-FS 2012). More rapid movement of the insect is made likely through the transport and distribution of wood packing material and infested pine logs (Evans-Goldner and Bunce 2009).

Roughly 25% of the forest communities on the Nantahala and Pisgah NFs have a conifer component. Densities of pine basal area are close to 100% in white pine plantations and Virginia pine stands as well as scattered shortleaf pine in low elevation mesic oak pine woodlands. Several species of pine, like Table Mountain pine, are already threatened in their habitat due to fire suppression. On the Nantahala and Pisgah NFs, susceptibility is predicted to be low. This pest will likely have the greatest impacts in the ecozones where pine is present in higher densities (pine oak heath, shortleaf pine, and white pine plantations).

Figure 13. Susceptibility to the sirex wood wasp across the United States.



Disease or Pest: Southern Pine Beetle

Background: The southern pine beetle (*Dendroctonus frontalis*) is one of the most destructive pests of pines in the southern United States, Mexico, and Central America. This insect killed approximately 4.5 million board feet of pine timber from 1973 through 1977 in the southern United States. This beetle is found from Pennsylvania to Texas and from New Mexico and Arizona to Honduras (Hain et al. 2011).

Pathology: Female beetles bore into the inner bark and cambium of the host tree species. Using pheromone attractants, mating males and other adults build the population in the host. Beetles also infect the tree with blue stain fungus. The galleries and fungus combine to girdle the tree (Clarke and Nowak 2009).

Forest Community Impacts: Within the Nantahala and Pisgah NFs, southern pine beetles can attack and kill all species of pines, but prefer shortleaf, Virginia, and pitch pines. Under extreme outbreak conditions, southern pine beetles are also capable of attacking and killing white pine, spruce, and hemlock (Clarke and Nowak, 2009). Within pine communities, infestations of southern pine beetles will lead to heavy mortalities within the pine overstory, and the release of the existing midstory and understory. In mixed pine/hardwood stands, smaller gaps may occur as overstory trees succumb. Reductions in pine basal area and reduction of species abundance may occur as forests lose their pine component.

Nantahala and Pisgah NFs Distribution: The southern pine beetle has been North Carolina's most significant forest insect pest. From 1999 through 2002, the beetle killed at least $84 million worth of timber in North Carolina. Most of the mortality during this outbreak was in the mountains and western piedmont areas (Birt 2011).

The Nantahala and Pisgah NFs contain roughly 113,665 acres (11%) of forest community types susceptible to southern pine beetles (USDA-FS 2001). Between 1960 and 2000, western counties of North Carolina endured a total of 15 years of epidemic infestation levels in some part of the landscape. The mid-1970s and early 2000s saw widespread epidemic populations and significant southern pine species mortality (Birt 2011).

Figure 14. Distribution of the southern pine beetle throughout the United States.

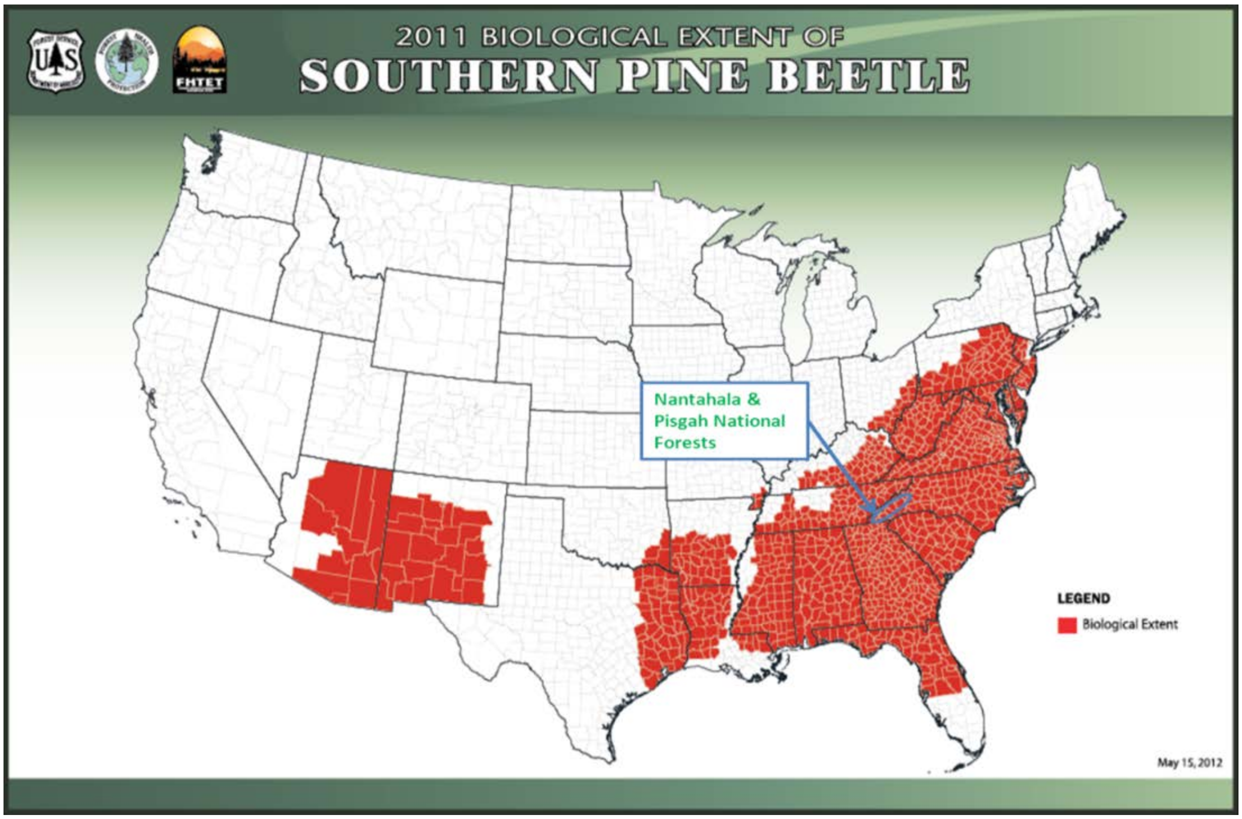
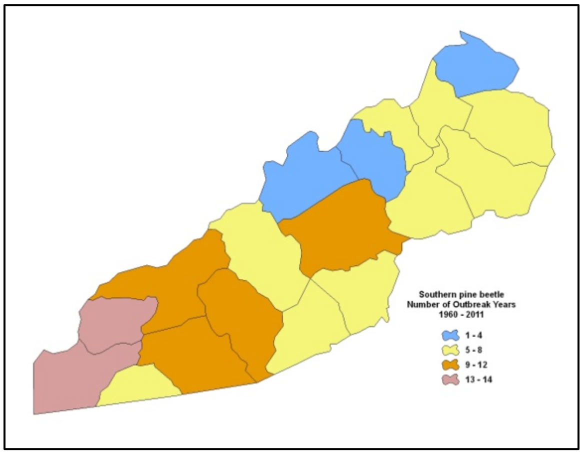


Figure 15. Inception of southern pine beetle in counties across western North Carolina.



Disease or Pest: Sudden Oak Death

Background: Sudden oak death was identified in California and Oregon in 1995 (O'Brien et al. 2002).

Pathology: This disease is caused by a fungus (*Phytophthora ramorum*). Infection results in a "bleeding" canker on the stem of red oak species and leaf spots and dieback on other species (O'Brien et al. 2002; Gottschalk et al. 2003).

Forest Community Impacts: Many oak species in the red oak group are susceptible to sudden oak death including northern red oak, which is highly susceptible. Other forest plant species that are susceptible include *Vaccinium* species and *Rhododendron* species (O'Brien et al. 2002).

Nantahala and Pisgah NFs Distribution: Currently, sudden oak death is only impacting oaks on the west coast of the US, however transportation of infected plant material causing oak death poses a grave risk to the oaks present in the Nantahala and Pisgah NFs (O'Brien et al. 2002; Gottschalk et al. 2003; Koch and Smith 2008). The fungus has been detected within water courses in four southeastern states including North Carolina (NCFS 2011), but the closest location of the disease to the Nantahala and Pisgah NFs is in northeastern Georgia (Chastagner et al. 2010). The fungus is not currently known to disturb oak trees in the eastern US.

Disease or Pest: Thousand Cankers Disease

Background: Thousand cankers disease was identified in eastern Tennessee in 2010, and in Virginia and Pennsylvania in 2011 (Seybold et al. 2011; Tiserat and Cranshaw 2012). At this point, its presence in the western US was suspected for more than a decade (Newton and Fowler 2009). Infected trees usually die within three years (Tiserat and Cranshaw 2012).

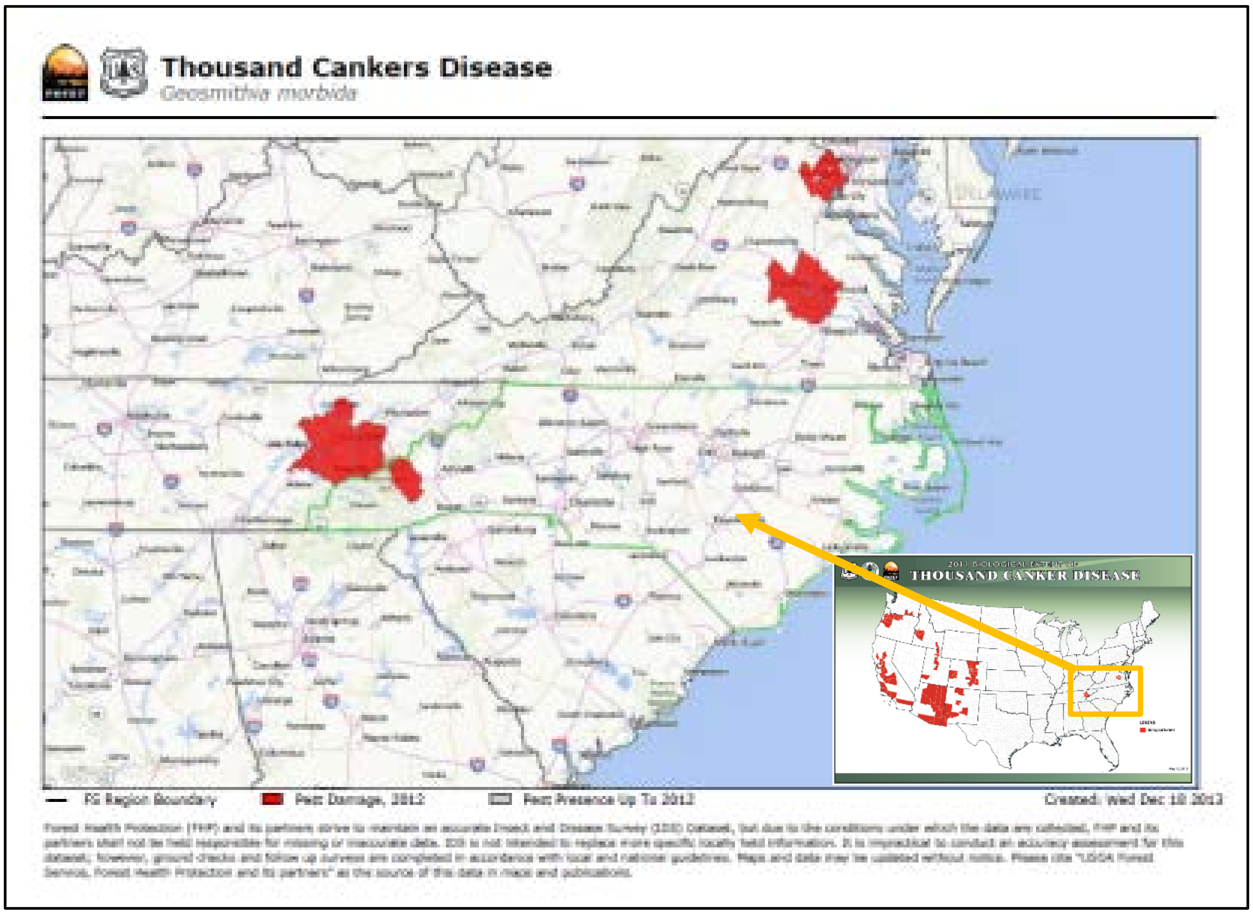
Pathology: Caused by a fungus in the genus *Geosmithia*, this disease is distributed by a bark beetle (*Pityophthorus juglandis*) native to the western North America (Newton and Fowler 2009;

Seybold et al. 2011). The disease kills walnut species as the bark beetle bores thousands of holes into the tree, each of which serve as infection sites causing wilt, dieback, and eventual mortality. It is suspected that human movement of walnut wood products is contributing to the spread of this disease (Newton and Fowler 2009).

Forest Community Impacts: Within the Nantahala and Pisgah NFs, the susceptible eastern host species is black walnut (Newton and Fowler 2009). Butternut does not appear as susceptible.

Nantahala and Pisgah Distribution: Though black walnut appears in small populations within the Nantahala and Pisgah NFs, it does exist. Its hard mast is important for wildlife species, especially with the presence of other diseases affecting many of the hard mast-producing species in the southern Appalachian forests. Thousand cankers disease is present in North Carolina in Haywood County. It is currently not known to occur on National Forest System lands.

Figure 16. Distribution of thousand cankers disease throughout North Carolina and the surrounding states and throughout the United States (see inset).



Disease or Pest: **White-nose Syndrome**

Background: White-nose Syndrome is a disease caused by a non-native, cold-loving fungus (*Geomyces destructans*) found in caves. The name of the disease refers to the white fungal growth found on the noses of infected bats. It was first discovered in New York in 2006, where evidence showed that up to half of the wintering bat population was killed. Since then, it is estimated that white-nose syndrome has killed more than 5.7 million bats in eastern North America. The fungus currently affects hibernating bat species in 16 states and four Canadian provinces.

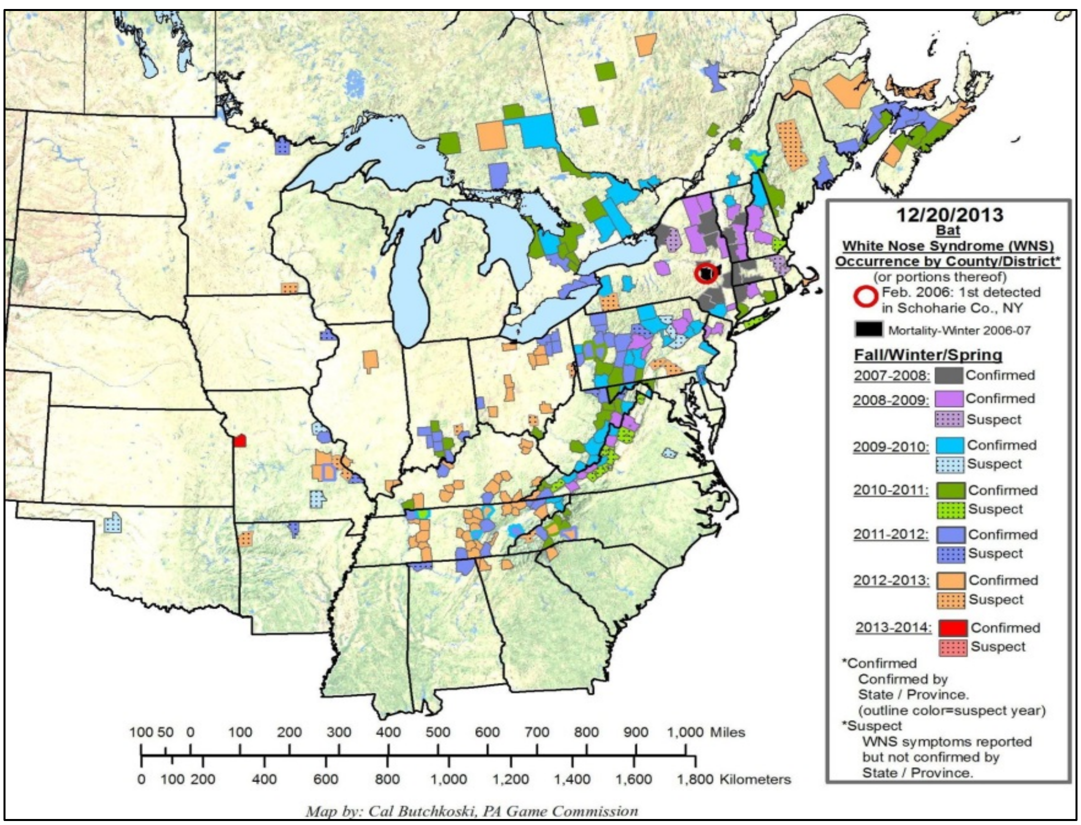
Pathology: *Geomyces destructans* is native to European caves, where it evolved with native bat species, allowing them to develop resistance. The fungus is transferred cave to cave by contaminated equipment and clothing used by both researchers and recreational users if it is not properly disinfected. It is hypothesized that human contamination may have brought the fungus to the United States. The fungus also spreads among infected bat populations.

Forest Community Impacts: Little brown bats, once a common bat in the area, are sustaining the largest number of deaths. Some caves infected with white nose syndrome are experiencing 90-100% bat mortality. Currently, five other hibernating bat species are affected by the fungus: the big brown bat, northern long-eared bat, tri-colored bat, eastern small-footed bat, and the endangered Indiana bat. The disease is spreading rapidly and has the potential to infect at least half of the bat species found in North America.

Research shows that bats infected with white-nose syndrome are emerging from hibernation as often as every 3-4 days, as opposed to the "normal" 10-20 days. The fungus damages the connective tissues, muscles and skin of the bats while also disrupting their physiological functions. The bats wake up dehydrated and hungry during the cold winters when there are no insects to eat. It is estimated that 90% of infected bats perish from starvation.

Nantahala and Pisgah NFs Distribution: Presently, white-nose syndrome is known from seven counties in North Carolina containing the Nantahala and Pisgah NFs.

Figure 17. Distribution of white nose syndrome throughout the eastern United States.



Disease or Pest: White Pine Blister Rust

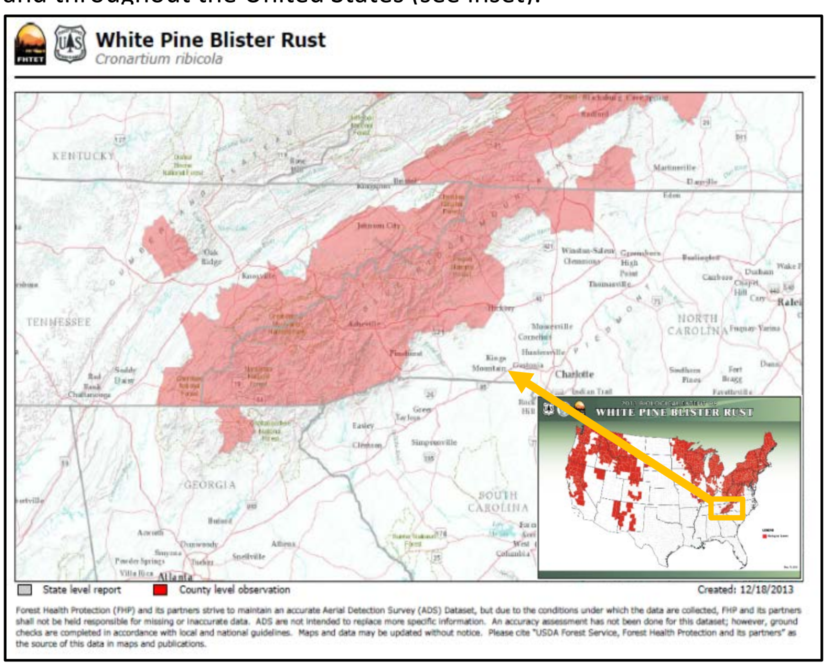
Background: First identified in North America during the turn of the 20th century, white pine blister rust has spread to both eastern and western white pines (Miller et al. 1959). The Forest Service and State Forestry Services started an extensive Ribes eradication program that lasted through the 1970s. This program coupled with efforts to breed resistance into eastern white pine have not proved overwhelmingly successful (Manion 1991).

Pathology: The complex disease cycle associated with the rust fungus (*Cronartium ribicola*) causing white pine blister rust affects most five-needle pines. To complete the cycle of infection the fungus must alternate parts of its life cycle on both the white pine and the shrub genus *Ribes* (Manion 1991). Cankers produced on the branches of infected white pine eventually spread to the cambium, and in combination with the formation of new cankers, will eventually girdle the tree. Transfer of the rust between the *Ribes* and eastern white pine occurs in the fall under cool temperatures with high humidity (Miller et al. 1959; Van Arsdel 1972). Temperatures greater than 95ºF are fatal to the rust (Van Arsdel 1972).

Forest Community Impacts: Very few white pine trees are resistant to white pine blister rust. Many areas of the US contain non-infected trees because the environmental conditions are not favorable for the disease (Van Arsdel 1972). Where the disease proliferates, eastern white pine is reduced or damaged. This disease can be particularly damaging in plantations.

Nantahala and Pisgah NFs Distribution: The incidence of white pine blister rust is low in the mountains of the Nantahala and Pisgah NFs. White pine blister rust reportedly reached western NC between 1943 and 1958 (Miller et al. 1959). A combination of factors including early fall temperatures commonly above the thermal limit for the fungus, lower incidence of *Ribes* in the forest, and the arrival of the optimum temperatures and humidity after leaf fall for the species likely limit its proliferation in the mountains of NC (Van Arsdel 1972).

Figure 18. Distribution of white pine blister rust throughout North Carolina and the surrounding states and throughout the United States (see inset).



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